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## (54) Refractometers

(57) A refractometer comprises a prism C having an input face Q for receiving an incident beam of radiation through a body of liquid whose refractive index is to be measured, and means for flowing the liquid over the input face Q before making a measurement in order to remove bubbles. The refraction of the beam is detected at the output face B by, as shown, a photodiode array A connected to digital circuitry (Fig. 2; not shown). The refractive index measurement obtained may be used as an indication of e.g. the specific gravity of battery electrolytes.

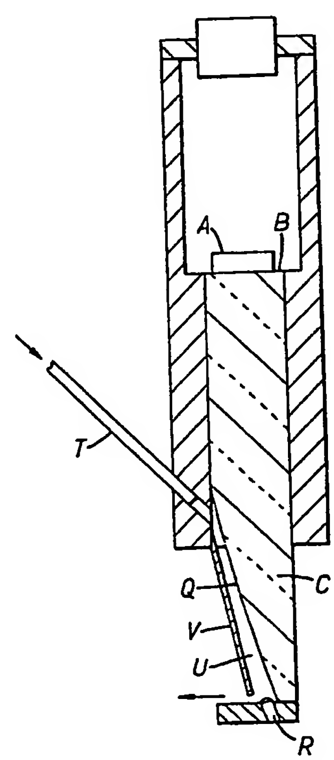


FIG. 1.

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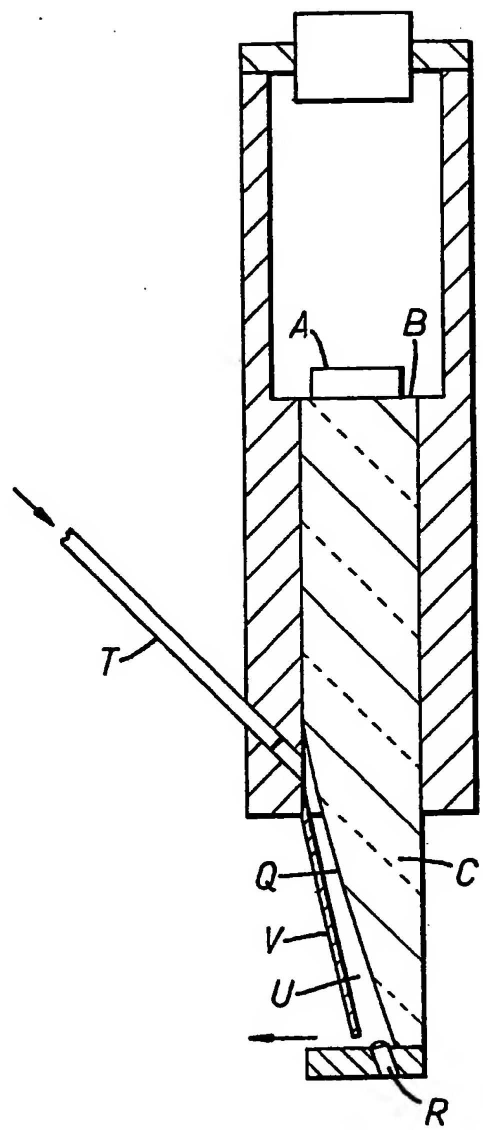


FIG.1.

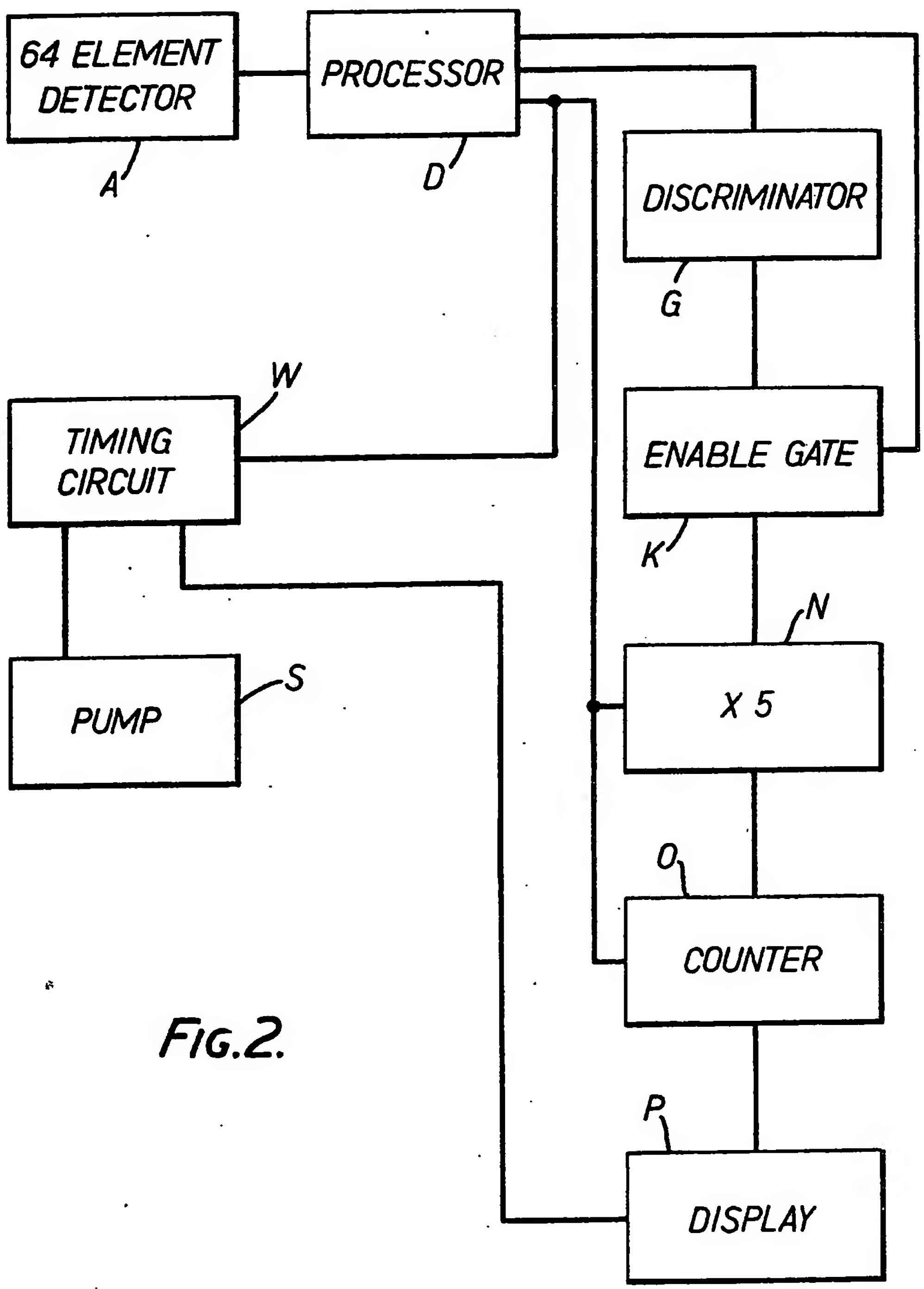
64 ELEMENT DETECTOR
A
PROCESSOR
D
DISCRIMINATOR
G
ENABLE GATE
K
TIMING CIRCUIT
W
PUMP
S
X 5
N
COUNTER
O
DISPLAY
P

FIG.2.

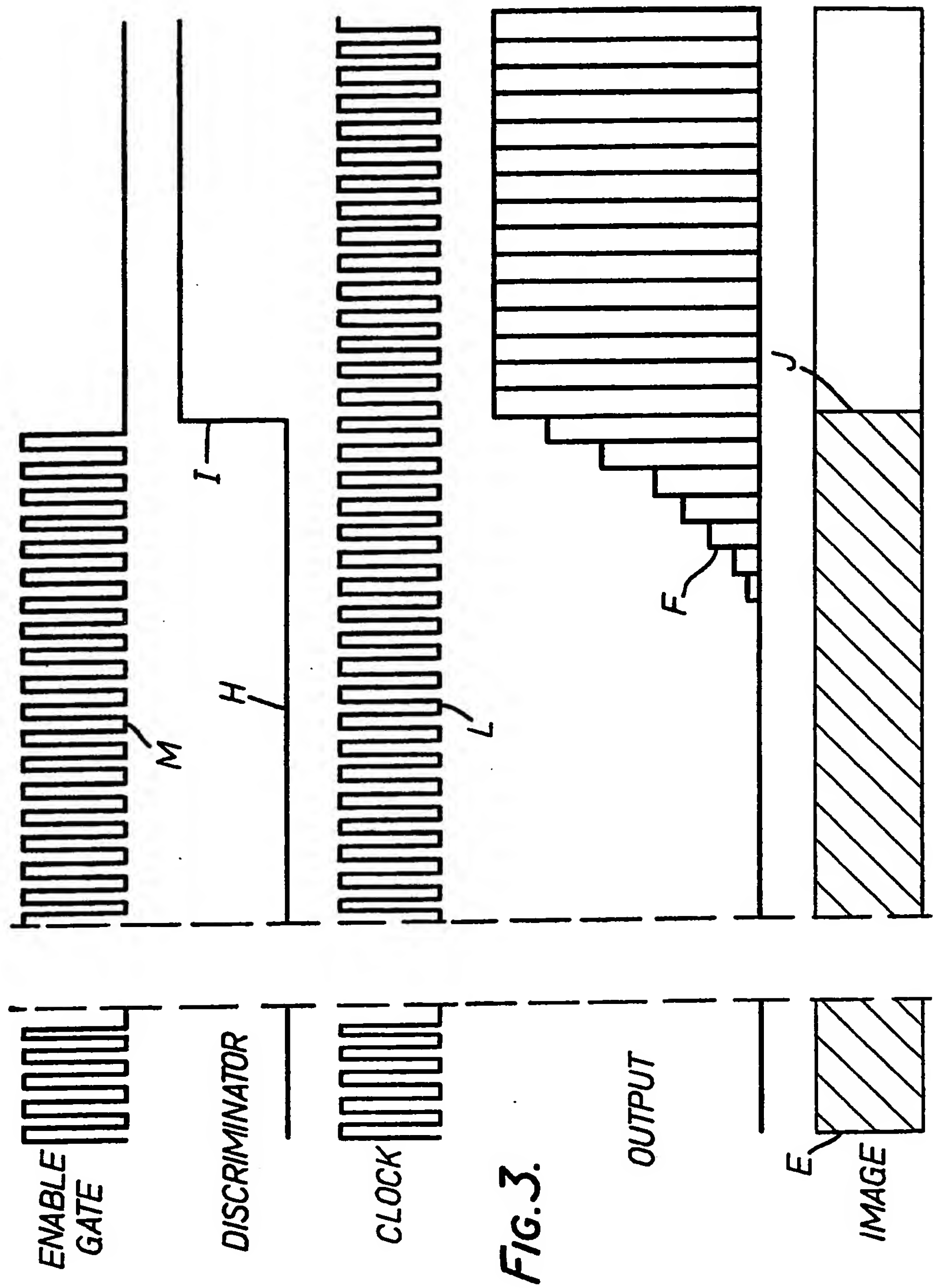


FIG. 3.

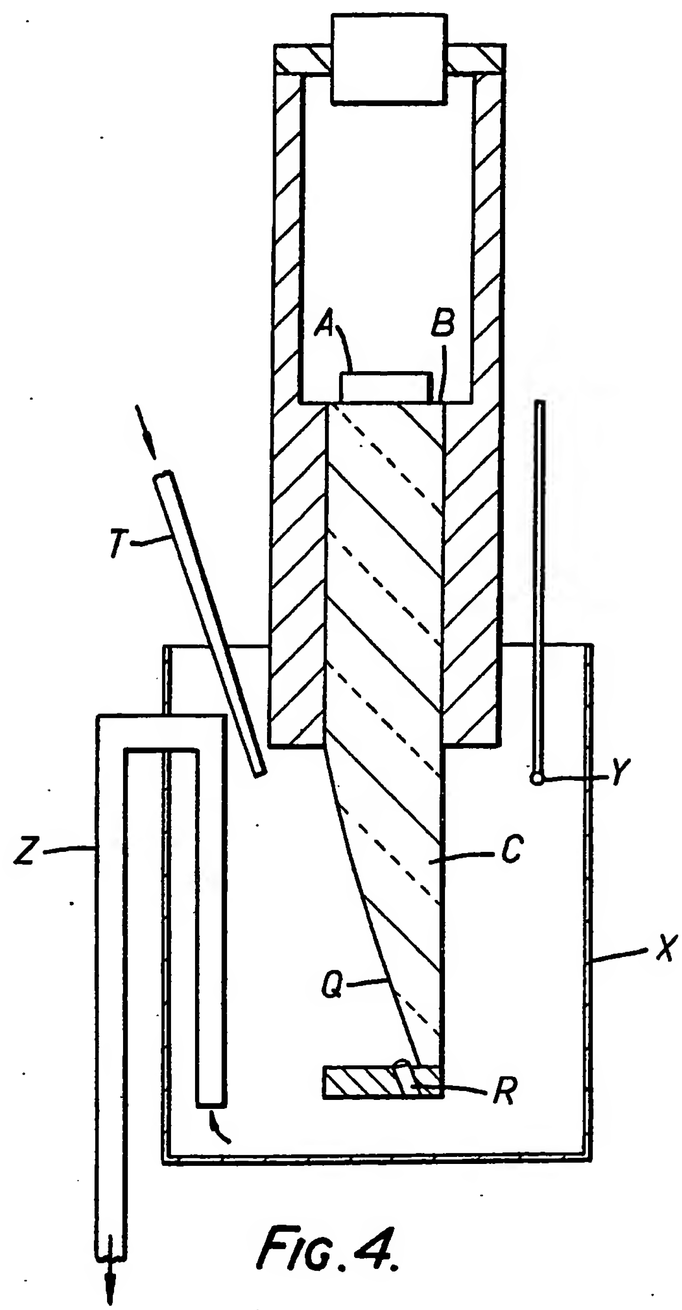


FIG. 4.

SPECIFICATION

**Refractometers**

This invention relates to refractometers and has a particular, but not exclusive, application to refractometers for measuring the refractive index of the electrolyte in electric storage batteries or accumulators, more especially those of the lead-acid type. In such batteries the refractive index of the electrolyte in a cell at a given temperature is a function of its specific gravity and hence of the degree of charge of the cell.

According to the invention a refractometer for measuring the refractive index of a liquid comprises a transparent prism having a receiving face and an output face, means for maintaining liquid in contact with the receiving face, means for transmitting through the liquid to the receiving face an incident beam of light (as hereinafter defined) a portion of which is refracted at the receiving face and passes through the prism as a sharp edged refracted beam which emerges through the output face with the edge of the beam at a position on the output face which depends on the refractive index of the liquid, means for detecting the position of the edge of the refracted beam, and means for producing a flow of liquid over the receiving face. The invention also relates to a method of measurement of refractive index using a refractometer as defined above.

The light may be visible light or, if preferred it may be a light of a wavelength outside the visible spectrum, for example infra-red. In any case the material of the prism must be transparent to light of the wavelength employed.

When the incident beam passes through a liquid having a particular refractive index, the sharp edge of the refracted beam emerging from the output face of the prism will be at a particular position relative to the output face, but if the refractive index of the liquid changes, then the edge of the refracted beam will be at a different position. The position of the edge of the refracted beam therefore gives an indication of the refractive index of the liquid. The surface of the output face may bear suitable scale markings either by having a semi-translucent screen or the output surface of the prism itself may be suitably marked. Alternatively, the beam may be intercepted by an array of light-sensitive sensors and signals therefrom converted to an appropriate visual or other indication. A scale indicating the position in the image of the edge of the refracted beam may be calibrated in any desired units, e.g. as the refractive index of the liquid or, in the case where the liquid is the electrolyte of a battery, as the specific gravity of the liquid.

The basic optical principle of the refractometer is essentially that of known prism refractometers of the dipping type having a prism intended to be immersed or dipped in the liquid whose refractive index is to be measured.

One disadvantage of dipping refractometers is that in the case of certain liquids, for example the acid in a lead-acid battery or accumulator, bubbles may form on the receiving face of the prism which may falsify a reading or make reading impossible. A usual method of clearing the bubbles from the receiving surface of the prism before making the measurement is to withdraw the instrument from the electrolyte, if need be wipe it, replace it, and take a reading before bubbles have had time to reform. The present invention enables the instrument to be used in an environment where bubbles tend to form on the receiving face of the prism, without the prism even having to be dipped in the liquid. This is achieved by the means for causing liquid to flow over the receiving face of the prism and the means for maintaining the liquid in contact with that face. The latter means may be a wall spaced from the receiving face, the space between the wall and the receiving face serving as a reservoir for the liquid. When a measurement is to be made, liquid is pumped into the space and allowed to drain away, to entrain and carry away any bubbles that may have formed. The space is then refilled with fresh liquid. The liquid outlet from the space is restricted to ensure that the space will remain filled while the measurement is being made. When the measurement has been made the pump is stopped and the liquid drains out of the space. The instrument can then be moved to another cell.

Alternatively the receiving face of the prism may dip into the reservoir of an hydraulic oscillator into which the liquid is pumped. As liquid is pumped into the reservoir, the receiving face of the prism will be covered enabling a measurement to be made. When the liquid level reaches a predetermined level the reservoir is rapidly emptied and any bubbles which may have formed will be entrained and carried away as before. The pumping may be continuous and a syphon may be used to limit that liquid level and drain the reservoir.

In order to form a refracted beam with a sharp edge the receiving face of the prism may be curved. The incident beam of light is caused to impinge thereon obliquely, such that in part of the width of the beam the light rays will strike the receiving surface at an angle less than the critical angle and will be refracted into the prism, whereas the light rays in the rest of the width of the beam will strike the surface at an angle greater than the critical angle and will not enter the prism but will be reflected. The disposition of the output face with respect to the receiving face should be such that the refracted beam is substantially normal to the output face, to obviate further refraction of the emerging refracted beam.

The source of the incident beam of light may be, for example, an infra-red light emitting diode. The light source may be located near one end of the curved receiving face of the prism so as to direct the beam obliquely onto the receiving face.

A specific embodiment of the invention, namely an instrument in the form of a probe for application to cells of a lead-acid type battery, is

illustrated in the accompanying drawings, wherein:

Figure 1 is a longitudinal section of the probe, with a wall spaced from the receiving face;

Figure 2 is a block circuit diagram of the detector apparatus;

Figure 3 is a diagram representing the various detector signals, and

Figure 4 is a longitudinal section of the probe dipping into the reservoir of an hydraulic oscillator.

As already indicated, one suitable means for detecting the position of the edge of the emerging refracted beam may be an array of light-sensitive sensors with appropriate apparatus for converting the signals therefrom. One such arrangement will be described by way of example in relation to the illustrated embodiment.

A detector A comprising a linear array of 64 photodiodes is placed against the output face B of the prism C in the path of the emerging refracted beam. The photodiodes are set at 0.004 inch centres. The range of the instrument, from 1.000 to 1.300 in specific gravity, is made to correspond to 60 of the array elements, each element thus representing a 0.005 increment in specific gravity.

The output from the detector A comprises 64 pulses, one from each of the photodiodes, the pulse height representing the light intensity falling on each individual photodiode. These are fed to a processor D. The processor also provides a synchonising pulse corresponding to the first diode of the array and a clock pulse which is in synchronism with the output pulses.

The output pulses corresponding to the image shown at E in Figure 3 are of the form shown at F. The output pulses are fed into a discriminator G which generates the waveform shown at H, the position of the step I corresponding to the position of the cut-off edge J of the refractometer image.

An enable gate K is fed with both the discriminator output and the clock pulses L from the processor and provides an output M consisting of a set of clock pulses only up to the discriminator step I, the number of these pulses being proportional to the specific gravity (refractive index) of the electrolyte at the refractometer face. Each pulse M represents an increment of 0.005 in specific gravity.

The pulses M are fed via a circuit N which allows five sets of such pulses to pass, (thus multiplying by five the number of pulses), to a counter O and to display circuits P. The pulses arriving at the counter O now each represent 0.001 in specific gravity and thus with a four digit display, the first digit of which is always 1, the display P reads directly in specific gravity.

Under normal conditions the update time of the circuit is very fast and is capable of updating every 11 mS. In a lead-acid cell, the position is complicated by very small bubbles of gas formed when the cell is charging. These bubbles form on the receiving face Q of the refractometer prism C and obscure the light source R, thus rendering the instrument useless. The only satisfactory method hitherto found for removing the bubbles is to withdraw the instrument from the electrolyte and then to replace it. Drawing the refractometer prism face through the electrolyte meniscus effectively wipes the face clean of the bubbles. Since the time taken for the bubbles to reform may be about 50 seconds a reliable reading may be taken shortly after the instrument has been replaced in the electrolyte.

In the present invention the clearance of bubbles is achieved by either the arrangement shown in Figure 1 of a wall V spaced from the receiving face Q of the prism C or by that shown in Figure 4, having the receiving face Q of the prism C dipping into the reservoir X of an hydraulic oscillator. In the former case the receiving face Q of the prism C is above the surface of the electrolyte in the cell, and a pump S (not shown in Figure 1) pumps electrolyte from the cell through a pipe T into the space U between the wall V and the curved receiving face Q of the prism C. A timing circuit W provides the following actions.

(1) The pump S is switched on to purge the pipe T and the space U with fresh electrolyte.
(2) There is a delay to allow electrolyte in the space U to drain out and remove any bubbles from the prism receiving face Q.
(3) The pump S is switched on again to fill the space U and, after a time sufficient for the space to fill it commands the display circuit P to read the specific gravity. This reading is held until the pump cycle is restarted.

A typical cycle time is 30 seconds.

The arrows in Figure 1 indicate the direction of flow of the pumped electrolyte.

In the second case, where the arranngement is as in Figure 4, the pump S operates continuously, pumping electrolyte from the cell, through a pipe T into the reservoir X of the hydraulic oscillator. Starting with the reservoir empty, the sequence of operation is as follows:

(1) The pump S pumps electrolyte from the cell through the pipe T into the reservoir X.
(2) The level of the electrolyte in the reservoir X rises until the receiving face Q of the prism C is covered, at which time a refractive index measurement is made. This condition may be detected by a liquid level detector Y situated at an appropriate level in the reservoir X. A signal from the level detector Y via the timing circuit W, commands the display circuit P to read the specific gravity. This reading is held until the level detector Y is next operated.
(3) When the electrolyte level in the reservoir X is sufficiently high the ciphon Z operates and the reservoir X rapidly empties removing any bubbles from the receiving face 4 of the prism C.
(4) The reservoir X is now empty and the cycle continues from (i) above.

A typical cycle time might be the same as before, 30 seconds.

The arrows in Figure 4 indicate the direction of flow of the electrolyte.

**Claims**

1. A refractometer for measuring the refractive index of a liquid comprises a transparent prism having a receiving face and an output face, means for maintaining liquid in contact with the receiving face, means for transmitting through the liquid to the receiving face an incident beam of light (as hereinbefore defined) a portion of which is refracted at the receiving face and passes through the prism as a sharp edged refracted beam which emerges through the output face with the edge of the beam at a position on the output face which depends on the refractive index of the liquid, means for detecting the position of the edge of the refracted beam and means for producing a flow of liquid over the receiving face.

2. A refractometer as claimed in Claim 1 wherein the detection means comprises scale markings on the output face of the prism.

3. A refractometer as claimed in Claim 1 wherein the detection means comprises a semi-translucent screen provided with scale markings.

4. A refractometer as claimed in Claim 1 wherein the detection means comprises an array of light-sensitive detectors and means to convert signals therefrom into an appropriate visual or other indication.

5. A refractometer as claimed in any of the preceding Claims wherein the detection means is calibrated to read the refractive index of the liquid.

6. A refractometer as claimed in any of the preceding Claims adapted for measurement on battery electrolytes wherein the detection means is calibrated to read the specific gravity of the electrolyte.

7. A refractometer as claimed in any of the preceding Claims wherein the means for maintaining liquid in contact with the receiving face is a wall spaced from the receiving face, the space between the wall and the receiving face serving as a reservoir for the liquid.

8. A refractometer as claimed in Claim 7 wherein the reservoir is provided with a restricted outlet.

9. A refractometer as claimed in any of the preceding Claims wherein the means for producing a flow of liquid over the receiving face comprises a pump.

10. A refractometer as claimed in Claim 9 when dependent on Claim 8 wherein the pump is operable to deliver liquid to the receiving face faster than liquid can drain from the reservoir through the outlet.

11. A refractometer as claimed in any of Claims 1 to 6 wherein the means to maintain liquid in contact with the receiving face and the means to produce a flow of liquid over the receiving face comprises a hydraulic oscillator.

12. A refractometer as claimed in Claim 11 wherein the oscillator comprises a reservoir containing the prism, a pump to deliver liquid to the reservoir, and means to drain liquid from the reservoir when the liquid reaches a predetermined level.

13. A refractometer as claimed in Claim 12 wherein the means to drain the liquid from the reservoir when the liquid reaches a predetermined level comprises a syphon.

14. A refractometer as claimed in Claim 12 or Claim 13 wherein the pump operates continuously while measurements are required.

15. A refractometer substantially as described herein with reference to the accompanying drawings.

16. A method of measuring the refractive index of a liquid with a refractometer as claimed in any of the preceding Claims wherein the liquid is caused to flow over the receiving face to carry away any bubbles or deposits which may otherwise form on the face.

17. A method as claimed in Claim 15 where the said flow of liquid is continuous while measurements are required.

18. A method as claimed in Claim 15 or Claim 16 wherein fluid is alternately held in contact with the receiving face by restricting the drainage therefrom and then rapidly drained therefrom.

19. A method of measuring the refractive index of a liquid substantially as described herein with reference to the accompanying drawings.

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